Basing the figures upon average numbers of operatives, the relative positions of the seven specified classes of work and the cost of production may be seen from the following table:

Per operative.	Heavy and coarse hardware.	Domestic and miscellaneous hardware.	Handicraft tools.	Saddlery hardware.	Light and fine hardware.	Builders' hardware.	Machinists' supplies.
Product	$1,777	$1,490	$1,449	$1,416	$1,409	$1,247	$1,008
Added value	921	715	893	746	806	680	747
Material	856	775	556	670	603	567	261

The reader will see that, upon the presumption of similar wages and incomes derivable from labor, the economy of the methods of manufacture must be greatest in builders' hardware and least in heavy hardware and handicraft tools. Upon the presumption of a similar cost per pound of material, machinists' and builders' hardware will be most and heavy hardware least costly for the same weight of material. While these presumptions are by no means strictly correct, they are not so far from correct as to invalidate these inferences. The figures for the several classes are also sufficiently distinctive to warrant the reasonableness of the classification as being founded not only upon the kindred uses of the articles manufactured, but upon kindred conditions of manufacture.

Each class will, however, from a statistical standpoint, exhibit examples of very different conditions. Two small factories in the same place, of about the same size, and both returned as manufacturing builders' hardware, have respectively per operative the following capital investments, wages, value of material, value of products, and ratio of product to material:

	Capital.	Wages.	Value of material.	Value of products.	Ratio of product to material.
1	$5,000	$550	$45,000	$50,000	1.11
2	500	500	100	1,500	15.00

These are extreme cases, but they stand side by side, the former, in ratio of product to material, ranking with such industries as the manufacture of lead shot, sugar-refining, milling (flour), and the currying of leather, and the latter in that respect ranking with the mining and fishing industries. Builders' hardware may thus be said to compass both industrial extremes in these two examples. The former may not be inconsistent with the manufacture of sash weights, spikes, brads, and cheap forgings, and the latter with the manufacture of the finest ornamental work, die-cutting, and special articles of hardware.

While in the manufacture of builders' hardware the value of the product averages about two and two-tenths the cost of material, in the manufacture of locks, latches, door bolts, and spiral-spring hinges the value of material is commonly increased more than threefold by the process of manufacture; while, on the other hand, the value of material is only increased by about one-half in the manufacture of ordinary butts, hinges, and staples. Thus, locks and hinges, the two most important products in builders' hardware, stand on either side of the average, locks being the finer and costlier and hinges usually the cheaper product. In large factories the weight of constituent material handled per operative per annum commonly ranges between 6,000 and 10,000 pounds, being, under other equal conditions, greater for a coarse than for a fine, and greater for a uniform than for a varied product.

In a large factory producing a high grade of goods in builders' hardware it was found that the percentages by weight of constituent material used were as follows: 54 per cent. pig-iron, 3 per cent. wrought-iron, 24 per cent. iron wire, 7 per cent. copper, 4 per cent. wrought brass, 3 per cent. brass wire, 2 per cent. lead, 2 per cent. spelter, and one-half of 1 per cent. each of tin and antimony. Copper and brass and brass materials thus comprised nearly one-fifth of all by weight, and at this time pig-iron was rated at 1¼ cents, wrought-iron at 4 cents, iron wire at 5 cents, copper at 18½ cents, wrought brass at 22 cents, brass wire at 26 cents, lead at 5 cents, spelter at 6 cents, tin at 18 cents, and antimony at 25 cents per pound, so that the average cost was about 5 cents per pound.

In saddlery hardware the product is, upon the whole, not as fine as in builders' hardware, but some articles, such as stirrups, nickel-plated ware, and harness ornaments and trimmings, are finer than the average of locks, having a higher ratio of values of product to material. The coarser products are hames and common forged and cast trimmings.

In making hand tools the average ratio of product to material is 2.61, but for watch and jewelers' tools it is sometimes as high as 10 or 15, and nearly as high for some kinds of shoe tools. For molding, broom, glass-workers', joiners', canners', and confectioners' tools and weavers' reeds the ratio is considerably higher than the average. On the other hand, as generally tending to reduce the average, we may note tinners' and hatters' tools, with which some light machinery is inseparably included (tinners' tools being also made upon a large scale), and tools of such ordinary usage that they are manufactured upon a large scale under more economical conditions than the average as screw-wrenches, screw-drivers, and bit-braces.

So, for the other classes of hardware, the goods made in small quantities and under less favorable conditions of economy, and the lighter and finer goods, will have ratios above the average, while the heavier and coarser goods, and the goods which, however fine, may be cheaply made in large quantities, have ratios below the average.

In heavy hardware the average ratio is 2.07, those above the average being hog-ringers, pump hardware, plumbers' hardware, and small hammers and steel castings, and those below the average are anvils, blacksmiths' tools, chains, and marine hardware.

In light hardware the average ratio is 2.34. Above the average are pianoforte hardware, draw pulls, stationers' and ornamental hardware, and iron toys; below, are coffin plates and undertakers' hardware (in many cases), buckles, cabinet hardware, and japanned goods.

In domestic and miscellaneous hardware the average ratio is 1.92, betokening a low productive efficiency. Above the average are ticket-punches, scales and balances, stair-rods, skates (generally), apple-parers, and stock-bells; below the average, water-filters, tinware and enameled ware, gun implements, and the more common articles of household and garden hardware.

In machinists' supplies (hardware) the average ratio is 3.86, indicating finer and more exact work than the average of any other class. Above the average are chucks, which require specially fine workmanship, and below, though but slightly, are twist-drills, taps, dies, stocks, and other steel tools.

To the casual observer, in looking over the census tables, these ratios appear so variable for goods large and small, light and heavy, without obvious distinction, that he is apt to jump at the conclusion that there is somewhere an inconsistency, and that the returns are so burdened with serious variations that their accuracy may be easily questioned; but a more thorough analysis, bearing all the facts in mind, shows that the returns, although in the nature of things imperfect, are fairly made, are consistent with each other, and are worthy of a high degree of confidence. The apparent inconsistencies, when examined, are found to be the indices of actual conditions, and furnish strong internal evidence of the correctness of the work. This is more plainly apparent in the division of the subject into classes, when it may be seen that the general average can be compared to a fulcrum, upon which are doubly balanced fineness against coarseness or cheapness of product and inferior against superior facilities of manufacture, these attributes being often notably the separate conditions of different manufactures acting to produce a common tendency.

A continual readjustment of these conditions is in process. As inferior facilities become superior, there is a tendency to preserve the extent of range of the industry (which might thus be diminished) by making the coarse and cheap article finer and more costly.

We are thus led to a brief study of the real significance of the changes in aggregate statistical exhibits of materials used and ratios of products to materials in the successive censuses of 1850, 1860, 1870, and 1880.

The value of material per operative was, in 1850, for hardware (raw material), $429; in 1860, for hardware (materials), $411; in 1870, for hardware, $645; for saddlery hardware, $490; for hardware and saddlery hardware, $622; in 1880, for heavy hardware, $856; domestic and miscellaneous hardware, $775; saddlery hardware, $658; light hardware, $603; builders' hardware, $568; handicraft tools, $556; machinists' supplies (hardware), $261; all hardware, $609; all hardware excepting saddlery, $601.

Also, the ratio of values of product to material was, in 1850, for hardware, 2.31; in 1860, for hardware, 2.48; in 1870, for hardware, 2.42; for saddlery hardware, 2.56; for hardware and saddlery hardware, 2.44; in 1880, for heavy hardware, 2.07; domestic and miscellaneous hardware, 1.92; saddlery hardware, 1.97; light hardware, 2.34; builders' hardware, 2.20; handicraft tools, 2.61; machinists' supplies (hardware), 3.86; all hardware, 2.20; all hardware, excepting saddlery, 2.24.

For all classes of hardware the amount of wages paid per operative per annum was, in 1850, $281; in 1860, $321; in 1870, $471; in 1880, $398. Of the range of prices of materials the condition of the New York market furnishes some evidence. In 1849–1850 and in 1859–1860 the conditions were similar, a steady or slightly-falling market, with a similar range of prices. In 1870 prices were higher, but had been steadily declining. Between the 1st of May, 1869, and the 1st of May, 1870, Scotch pig had fallen from $41 50 to $35 and English bar from $85 to $75 per ton, and copper from 24 to 18¾ cents per pound. American pig and other materials also declined, but prices were still much higher than in 1859–1860, when Scotch pig ranged from $27 to $22 50, and English bar from $45 to $41 per ton. But in 1879–1880 the conditions were more peculiar, there being a great and a rapid rise in iron, copper, and other supplies, followed by a reaction and fall. American pig, for example, advanced from $17, in May, 1879, to $35, in January, 1880, and $40 in February, falling to $36 in March and $24 in May, 1880; and, in view of these great changes, the degree of uniformity exhibited in the returns of the cost of materials is much greater than might have been expected, although the diminution in the ratio of values of product to material in 1880, as compared with 1870, is doubtless principally due to this violent fluctuation.

But with the conditions thus fairly outlined we may consider that in 1860, as compared with 1850—

a. The fineness of product was slightly increased.

b. The cost of materials was not notably changed.

c. The economy of manufacture was increased, notwithstanding the small change in the size of establishments (from an average of 21 to an average of 24 operatives each) and despite the increased wages paid. This was a period of notable mechanical development, and the introduction of sewing-machine manufacture and the more general and wholesale production of manufacturers' supplies stimulated better organization and better facilities in the manufacture of hardware.

In 1870, as compared with 1860—

a. The fineness of product was considerably increased, the large fortunes resulting from the development of the country and the disturbance of values by war having led to more luxurious conditions of living, which demanded a finer class of hardware.

b. The cost of material was greatly and abnormally increased.

c. The economy of manufacture was probably diminished; wages were much higher, factories averaged no larger, and management was probably on the whole less close and careful, while investments obtained a larger income. Such improvements as were made in the details of processes could not compensate for these influences.

In 1880, as compared with 1870—

a. The fineness of product was still further increased. The artistic element in hardware products had become more prominent, and more exact methods were employed and better goods produced in nearly all classes of hardware.

b. The cost of material was diminished, but violent fluctuations in the market have given it a higher statistical showing than would have occurred under more equable conditions.

c. The economy of manufacture has been greatly increased. Wages are lower, relative to the value of the product, but labor is more steadily employed, and the diminution in expenses and incomes has been relatively greater than that of the cost of labor. Factories are larger, the average having increased from 23 to 35 operatives per establishment, and improved facilities in light molding, grinding, and forging have contributed to reduce the cost of manufacture. The growth in economy has more than compensated for the improved quality of the product.

In fuel there is a tendency to the more extensive use of coal, both as displacing wood and as consequent upon the larger proportion of steam-power used. In a large (steam-power) factory the cost of fuel is ratable at about 8 or 10 per cent. of the cost of all materials, about seven-tenths of it being for power. Mill supplies, such as coal, grit, glue, emery, belting, files, and oil, in a large builders' hardware factory may be estimated as costing from one-third to one-half as much as the constituent materials (or those which go into the product).

SYSTEM.

The manufacture of hardware involves many large and complete factory organizations, some of these factories manufacturing thousands of different kinds of articles, but the whole is not generally unified by an assembling department. There is no combination of these parts into machines, and each article might be made the basis of a distinct manufacture. It will thus be seen that the organic system in these large works may be described as a more artificial one than in any other class of manufacture. Multiplicity of details, and details not absorbed in a comprehensive scheme, require detailed management, which can best be secured by the subcontract and piece-work systems.

In a factory making a great variety of articles it is obvious that the division of labor must be based upon the kinds of work to be done upon them, and not upon the articles themselves. The former division is comparatively simple. The work to be done is brass and iron founding, press work, milling, drilling, wire-working, butt-riveting, grinding, polishing, japanning, and so on, but many articles of hardware are subjected to only two or three of this limited number of kinds of work, and the system is so far simplified.

The operation of a strict subcontract system is about as follows: It is proposed often by inventors or outside parties to manufacture a new lock, shade spring, hinge, tool, ornament, or other article in hardware. The superintendent of the factory knows to what contractor or piece-man it may be desirable to intrust all or portions of the work in question, and estimates with him for the performance of the work. Piece-work of any ordinary kind has its rate of labor pretty closely established, and where subcontractors are largely employed their time and the time of their men upon various jobs of work is carefully kept and made the basis of future contracts. In some cases a subcontractor will employ a considerable number of men, but a more common practice is to have the piece-men subordinated to salaried foremen. In large factories there is usually one foreman or subcontractor to from 20 to 50 operatives.

A large hardware factory is conducted upon the same administrative principles and with the same division of labor as in the manufacture of interchangeable mechanism, but actual uniformity follows as a consequence of labor-saving methods rather than as an end deliberately sought. Uniformity in systems of gauging is a great desideratum, especially in wire-working. Wire-gauge numbers are empirical, and refer to a variety of different standards, generally irregular in their divisions, differing among themselves both in design and in make, and all subject to irremediable variations, due to wear. It is therefore desirable to have gauges which may be adjusted to take up wear, and to have these periodically tested with reference to standards so infrequently used that their wear will be inappreciably small. It is obvious that for numbered sizes of holes and slots, subject to different usage and different degrees of wear, there is no practicable method of adjustment. Such adjustment is only practicable for gauges based upon uniform scales of measurement, such as the micrometer gauges.

The confusion of standard gauges, often involving misunderstanding and loss, is a subject of complaint from nearly all wire workers and makers, and the legal responsibility is often a matter at issue. Of two guage holes numbered alike, but worn to different dimensions, it may be hard to make a specification that will hold; but a specified measure upon a standard scale does not admit of this controversy.

The manufacture of the articles classified as machinists' supplies (hardware) is a fine class of machine work, and is done by the highest skilled class of machinists, technically known as tool-makers. The nicety and accuracy required in this kind of work is great and is slowly done, and the productive efficiency is small.

Hand tools are to a large extent made by small job-work. This reduces the productive efficiency, as the statistics plainly indicate, and the average number of operatives per establishment is the smallest in any class, viz, 12.

The highly-organized factories, with large forces of operatives, are mainly engaged in the manufacture of builders', light, and saddlery hardware.

CAPITAL.

As a rule, in the growth of manufacturing facilities the larger the size of the factory the greater is the relative amount of capital required for each operative. It might be supposed, upon a general theory of wholesale supply, that 1,000 men could be provided with shop-room and facilities together at a cheaper individual rate than one man working by himself; but while one man or a few men may work in a dwelling-house or in a cheap shanty upon cheap land, the thousand men require costly factories, fitted with costly tools and appliances, and often located upon expensive city land. It is their efficiency in working together that compensates for these conditions, but they cannot make shift with poor tools and cheap buildings; they require a city to dwell in, and their presence makes capital out of the very land on which they tread, and makes it taxable for their public benefit.

The returns of capital have been more full in the later census years, but the continuous increase in capital investment per operative from 1850 to 1880 in the manufacture of hardware is principally due to the growth of factories and facilities. Under ordinary conditions, the real capital investment per operative for a large factory can scarcely fall below $1,000, and is often much greater; but probably no man would think of erecting and equipping a large factory and establishing the manufacture on an estimated investment of less than $1,000 per operative.

The cost of machinery is not usually as much as one-third of the capital investment for builders' hardware, as the machinery is light and not generally costly, and a large proportion of the operatives are not machine tenders. In a number of cases the value of power machinery, exclusive of steam-engines and boilers, was found to range from $125 to $200 per operative employed.

LABOR.

Primarily, demand is the true gauge of productive efficiency. If we refer back to the examples of articles in the seven specified classes whose average ratio of values of product to material is below the average of the class, we will find that, as a rule, they are the articles in most common demand. But in the benefits of manufacturing facilities warranted by a large demand articles for which the demand is much smaller become the sharers, since, as has been before remarked, the division of labor is not usually respective of the articles, but of the kinds of work upon them.

In the larger and better-organized establishments there have been some important labor-saving developments within the past decade. From one-third to one-fourth of the operatives are often engaged in bench molding, and machinery introduced since 1870 has increased the productive efficiency from 20 to over 50 per cent. in many cases, but its introduction is somewhat retarded by the prejudice of operatives, so that in general usage much of the advantage remains to be utilized.

In one factory the improvement in productiveness per operative since 1870 is exactly known from piece-work records to be as high as 80 per cent. in specific instances, and is on the average 50 per cent. greater, 25 per cent. of which may be rated to be due to better machine methods and 25 per cent. to more thorough system. In another case it is stated that 200 men do the work which required 300 men in 1870, the advantage being mainly due to grinding with emery in place of filing, dip instead of brush japanning, and machine instead of hand molding. In one item of work, milling-machines superseding filing enabled an unskilled man at $1 50 a day to do three times the previous work of a skilled man at $3 a day. Such examples are by no means infrequent, but since, in the competition of business, they are used to cheapen the product, the general public soon reaps the advantage, and but a slight impression is made upon statistics.

The advantages derived may be classified as temporary and permanent, the latter embodying new practices so generally applicable that, once introduced, they permanently replace less effective methods. Of this character is much of the advantage gained within the past decade. But some advantages are temporary; efficient managers pass away, and their systems are not maintained; and factories run down in management, and are again brought to better efficiency without regard to the general practice. So an improved machine method may be applied in the fabrication of a special product. The demand for the product passes away, its manufacture ceases, and the method is dropped, but is presently revived and found applicable to the manufacture of another article. It will thus be seen that some examples of improvement may always be found by which the general practice is not necessarily advanced.

Labor-saving methods show some very striking results in their effect upon the division of labor, the labor saved being applied to other work, or to less efficiently performed duties in the same manufacture, and disappearing from its former sphere, the number of operatives upon unimproved portions of the work becoming relatively enlarged. In a single case of an improved machine process the proportionment of the whole number of operatives employed on the various kinds of work in the manufacture involved is as follows:

	Per cent.
Forging	9
Grinding	10
Metal working by machine	25
Packing and other work	56

With the hand labor displaced, the estimated division of labor would have been:

	Per cent.
Forging	5
Grinding	6
Metal working by hand	57
Packing and other work	32

In another manufacture (wire-working) the division of labor is:

	Per cent.
Wire-working by machine	23
Japanning, tempering, etc	23
Packing	54

To have done the same work by the hand methods displaced and still in vogue in foreign countries the division of labor would have been (as estimated):

	Per cent.
Wire-working by hand	79
Japanning, tempering, etc	5
Packing	16

These are extreme but actual cases. Of course the relative advantage of machine over hand work cannot be drawn directly from the percentages shown. In the former case the advantage of machine over hand work is fourfold, and in the latter it may be modestly estimated at fifteen-fold.

But while these influences have been emphasized by exceptional illustrations, in the ordinary run of hardware manufacture they are at work to a less marked degree. Thus, if a third of the operatives of a factory are bench-molders, and a third of the labor of bench molding is saved (some practical founderymen claim a much higher saving) by the use of presses, the relative number of operatives required for bench molding is reduced from 33⅓ per cent. to 25 per cent. The numerical inferences to be drawn are, for the same number of operatives, nearly 11 per cent. greater productiveness; for the same productiveness, 8⅓ per cent. fewer operatives; and for the same number of men in the foundery, 33⅓ per cent. more operatives in other departments. Human activity must find employment, and the satisfaction of one want only makes way for another; and thus it is that labor-saving devices make more labor than they save, and a factory in the above case would be more likely to employ thirty additional operatives than to discharge eight. But the alteration in the conditions of labor is more than numerical. Skilled labor is often displaced and unskilled labor substituted.

This substitution of unskilled for skilled labor is the burden of the claim of nearly every labor-saving invention, but, despite the fact that the past thirty years have witnessed an almost incessant introduction of devices for diminishing the cost of labor, we find that the wages paid per operative per annum have relatively and intrinsically been continuously on the increase. The multiplication of wants and of the manufactures to supply them gives the operative a greater range of choice and more freedom of movement. Intelligence is more in demand, and although the line between skilled and unskilled labor may now be less clearly defined than formerly great numbers of so-called unskilled workmen get higher wages than the journeymen craftsmen of former times.

It is believed that workmen of every grade will average higher skill and intelligence now than ever before in this country, and these workmen are producing the finest character of work with a rapidity which the world has never before seen equaled. In the lower grades of work the operatives are intelligent and adaptable; they work well together and require comparatively little oversight. Of the higher class of skilled artisans we can scarcely speak with too much respect. They have not only built up great organizations of industry and managed them with consummate skill, but they have encouraged the liberal and scientific education upon which their maintenance depends. Great managers and representative men have, however, existed in all countries and ages; and the elevation of the intelligence of the common laborer, so important in the industrial system, is more peculiar to this age and to this country.

The economy of large manufacture and uniform methods is largely due to the fact that so little labor is wasted. A small shop, with a local market or custom, often has to wait for work, and the craftsman labors leisurely, under the impression that he is working himself out of a job. In a large shop, with a continuous supply of work, all this wasted time is utilized, and at once the product is cheapened and the aggregate amount of wages paid per operative is increased. It is believed that the methods of uniform manufacture have taken such a hold upon American practice that American workmen are accustomed and disposed to work more uniformly and steadily and to crave fewer holidays and dissipations than are common to the cheaper labor of foreign countries.

In the manufacture of hardware skilled laborers are usually paid between $2 and $3 and unskilled laborers between $1 and $1 50 a day; but the great variation that exists in the rates paid is evidence that the line between the skilled and the unskilled laborer is very difficult to draw, and that respect is paid to different variations of usefulness. The prevalence of piece-work is also an important influence.

The employment of women and children in the manufacture of hardware is shown in the following tabulations. Of the numbers comprised under the head of children and youths, very few are small children, their employments being generally at variance with the sentiment of communities, if not prohibited by their educational laws. The lowest rates of unskilled wages (50 to 75 cents a day) will usually be found to be paid to children and youths.

Women are employed chiefly in packing the lighter articles of hardware, sometimes also in tending light machinery, and as clerks in offices.

Taking the seven specified classes of hardware, the following are the percentages of men, women, children, and youths, and women, children, and youths employed:

Class.	1880.			
	Men.	Women, children, and youths.	Women.	Children and youths.
Saddlery hardware	77.0	23.0	11.4	11.6
Light hardware	81.6	18.4	10.7	7.7
Builders' hardware	86.2	13.8	4.1	9.7
Machinists' hardware	88.1	11.9	6.9	5.0
Domestic hardware, etc	89.8	10.2	2.3	7.9
Hand tools	92.7	7.3	2.5	4.8
Heavy hardware	93.6	6.4	1.2	5.2
All hardware	84.9	15.1	5.8	9.3

In contrast with this the percentages in 1870 were 82.4 per cent. men, 17.6 per cent. women and youths, 8.1 per cent. women, and 9.5 per cent. youths. In 1850 and 1860 the numbers only of male and female operatives were given, the percentages being: 1860, male, 88.2; female, 11.8; 1850, male, 87.5; female, 12.5.

To explain the diminution in the proportion of women, children, and youths employed, and especially of women, we have merely to say that the development of resources due to labor-saving methods permits the support of a greater number of dependents, and points for extreme contrast to those foreign countries in which there has been little labor-saving development, while the family sustenance of certain classes is eked out by the labor of women in field-farming, shoveling, and other heavy work.

Examples of the change in the employment of women and youth in hardware manufacture are also given for several states:

CONNECTICUT.

Year.	PERCENTAGE.		
	Women and youths.	Women.	Youths.
1870	22.6	13.2	9.4
1880	15.1	8.8	6.3

MASSACHUSETTS.

1870	5.0	3.2	1.8
1880	7.0	3.1	3.9

NEW YORK.

1870	15.1	3.1	12.0
1880	15.7	3.0	12.7

OHIO.

1870	7.1	1.4	5.7
1880	9.2	1.5	7.7

PENNSYLVANIA.

1870	22.1	5.7	16.4
1880	16.0	2.3	13.7

ILLINOIS.

1870	10.7	1.4	9.3
1880	14.9	0.5	14.4

MISSOURI.

1870	3.0	....	3.0
1880	0.9	....	0.9

It will thus be seen that the diminution in the relative number of women employed is not a mere adventitious circumstance, but occurs, almost without exception, in every state.

In the manufacture of saddlery hardware in Connecticut the percentages of men, women, and youths employed were: In 1870, 69.7 per cent. men, 23.6 per cent. women, and 6.7 per cent. youths; in 1880, 56.3 per cent. men, 38.1 per cent. women, and 5.6 per cent. youths.

PROCESSES.

In previous reports allusion has been made to most of the processes employed in the manufacture of hardware. The distinctive kinds of work may not be numerous, but their applications are infinite. Within understood limits material of the same kind is usually submitted to a similar character and course of processes.

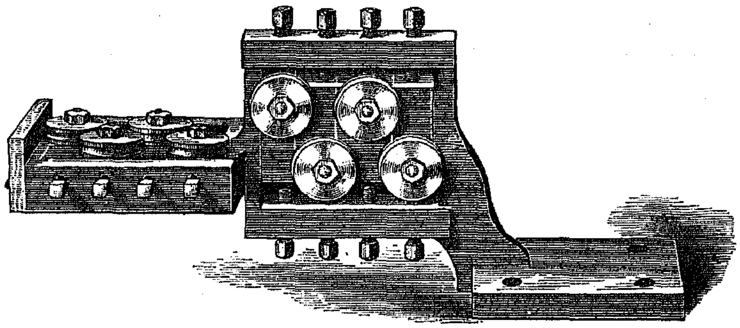

FIG. 1.

Brass and gray- and malleable-iron castings, after tumbling and filing, are usually more or less finished by milling, drilling, and grinding. Merchant-iron and steel are die-forged from the heated rods into small articles, usually by means of drops or pony hammers, and are finished by the usual machine processes. Small iron and wire are coiled into springs, or forged, turned, threaded, and pointed for screws, pins, rivets, nails, studs, and the like, mostly by special machinery. Steel plates are rolled, straightened, sheared, or punched to shape, and are milled, ground, hardened, and tempered. Press work is employed in punching, bitting keys, and shaping brass ornaments, nail heads, and other articles. The most ordinary divisions of a hardware factory are the founderies, the grinding-shop, the press-room, the machine-shop, and the japanning-room, and in some work such light assembling is required as the riveting of butts and the fitting of lock parts. Butts are often riveted by machinery, but sometimes by hand. The fitting and riveting of lock parts is commonly bench work.

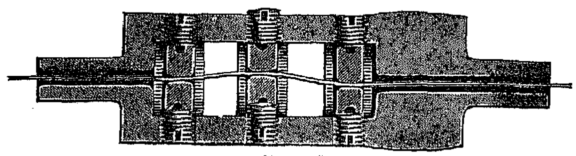

FIG. 2.

For the general run of hardware manufacture we may estimate that about two-thirds of a horse-power per operative per hour is employed, but the power used ranges from 0 to 2 or more horse-power, and in several of the largest factories, manufacturing a fine class of goods, the power employed was found to be about one-third of a horse-power per operative per hour.

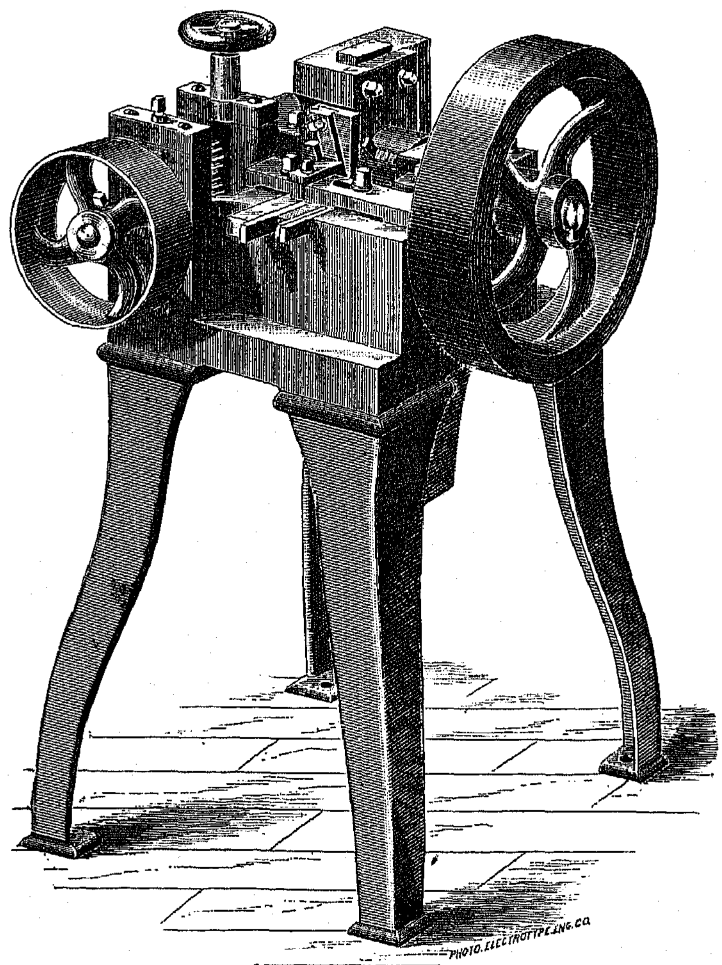

FIG. 3.

In making pottery knobs, which is accessory to the manufacture of builders' hardware, the processes are: Mixing and grinding clay, wire-cutting, biscuiting, baking, pressing, trimming, glazing, and rebaking. Biscuiting is the rough-shaping of the clay for the knob, leaving it in appearance like a biscuit. Pressing in a form after the first baking brings it to the true rounded shape. The baking is done in great furnace kilns, bound with iron, in one case three heats a month being usual, and one furnace having a capacity of 60,000 knobs or biscuits.

The operations of wire-working require especial mention, as this has been during the past ten or fifteen years one of the most fruitful fields for the introduction of labor-saving machinery. In this connection reference may be made to such manufactures as wood-screws, staples, fish-hooks, spiral springs, and horse nails, in some of which the efficiency of production has been advanced many fold over hand methods.

In wire-working, the straightening of the wire (which is drawn from coils) is the first essential operation. Old Connecticut clock-makers will recollect the time when it was customary to straighten wire by running it through between three nails driven in a board. Straighteners now used are of two styles, roll straighteners and rotary straighteners. An example of a roll straightener is shown in Fig. 1, the rolls being adjustable for wires of different sizes and stiffness. In Fig. 2 a section is shown of a rotary wire straightener with wire passing through the center. This is adjustable by setting the dies with a screw-driver. If the middle die is not set enough out of line, the curve is not taken out of the wire; but if it be set out too much, it runs out the wire with kinks or crooks. The adjustment is made by trial. The number of dies is not always limited to three.

Of staple machinery an example is illustrated in Fig. 3. This class of machinery is often of more complicated design. It generally operates by bending the wire upon a series of forming dies, after which it may be cut off square or pointed or barbed by an automatic tool. In this way staples, buckles, fence-barbs, coffin-handle wires,

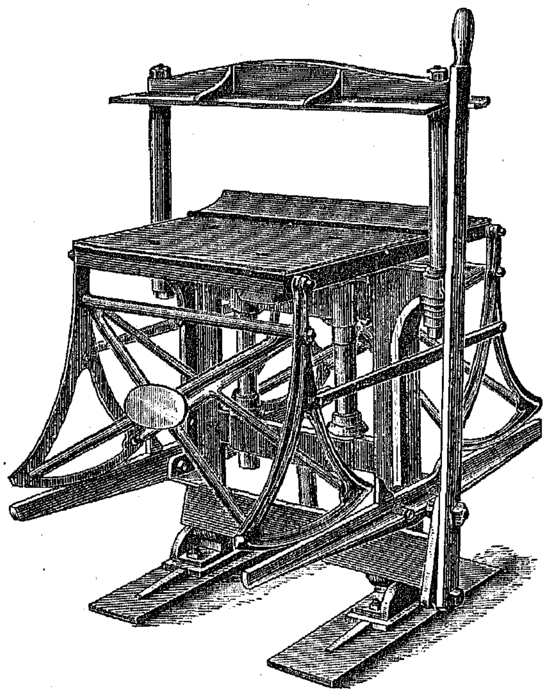

Fig. 4.

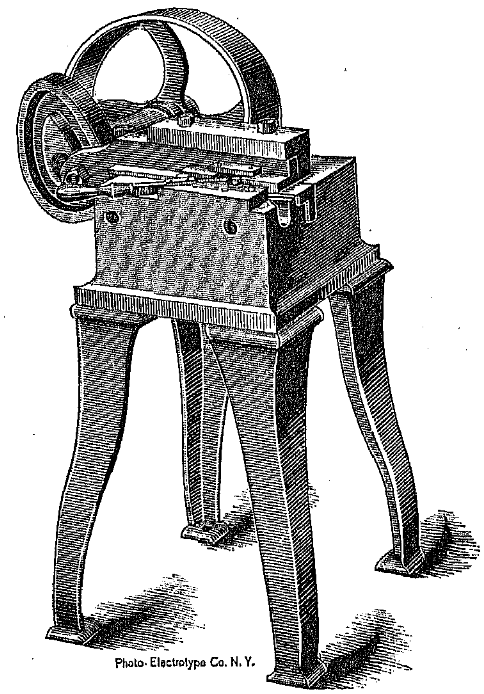

Fig. 5.

and a vast variety of other small articles are made; for example, the curved rims of padlocks are shaped by bending upon a die. The machine illustrated has not a very wide range of work, but it is automatic, taking wire from the coil and cutting off, forming, and pointing shear-point staples at the rate of 500 a minute. An automatic machine for making buckles, rings, and many other small articles from the coiled wire turns them out at the rate of from 75 to 175 a minute. Barbed blind staples are in a similar manner produced at the rate of 250 a minute.

Cold-roll pointing machines are useful in pointing bright articles which would otherwise have to be pointed by a blacksmith and rebrightened. Such a machine is stated to effect a saving of from two-thirds to five-sixths in the expense of this work.

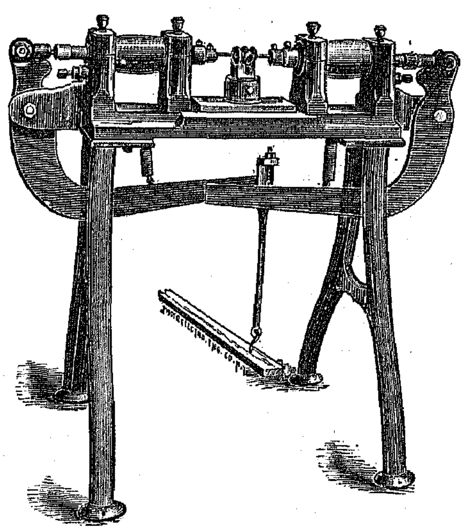

Fig. 6.

The manufacture of barbed fencing is an example of what may be done in special machinery, if only the incentive of a large demand is offered. Some of the machines for making fencing not only cut, bend, and sharpen the staples, but tie them in knots upon the strands of fence-wire, which is run off in measured reels, ready for the market, at the great rapidity of 100 knots of barbs a minute, 5 inches apart, and sometimes in excess of this rate. Reeling is a matter of special difficulty, the barbs piling upon each other unmanageably if they are not placed and wound with great precision. Galvanizing is also done with great rapidity, the wire running continuously through furnaces, zinc baths, coolers, and brushes, and the galvanizing being perfect.

But for these rapid and ingenious methods of manufacture it is questioned whether barbed-wire fencing, which already has so wide a field of usefulness in agriculture and stock-raising, might not have remained too costly for farm purposes.

Of the saving due to the use of molding presses much has been said. A saving of from 10 to 75 per cent. is claimed in special cases, probably from one-fifth to one-third in the ordinary run of bench molding. This improvement originated in and is due to sewing-machine manufacture, under which head many specific advantages of its efficiency are given. The original rocker press, or Broadmeadow & Eames machine, is shown in Fig. 4, and began to be introduced about 1873, Mr. Eames being foreman of the Wheeler & Wilson Company's foundery at Bridgeport, Connecticut, and having been previously mentioned as identified with improvements in the manufacture of fire-arms. Ordinary snap-flasks are used with the machines, the Eames machine taking a 26-by-20 inch flask. The Reynolds and Hammer machines are designed for lighter work and smaller flasks. In these, instead of the lower plate being brought up, as in the rocker machine, the upper plate is movable, being carried by a pair of pivoted arms or rods.

Wood screws are made by automatic machinery: cutting-off and heading, shaving and slotting, and chasing or screw-cutting machines. One person attends two heading, or four shaving and slotting, or three chasing machines, the average attendance for wood-screw machines being one person to nearly three and a half machines. The screws are produced with great rapidity, varying with the size of screw, heading being the most and chasing the least rapid operation.

But rapid as is the production of screws by machine cutting, they may be even more cheaply produced by rolling, and, thus made, are of a quality suitable for many purposes. In Fig. 5 is given an illustration of a thread-rolling machine, the thread being produced by compression between a pair of dies, one of which is stationary, while the other has a sliding movement.

The operations of drilling furnish a fertile field for labor-saving improvements. Fig. 6 is an illustration of a

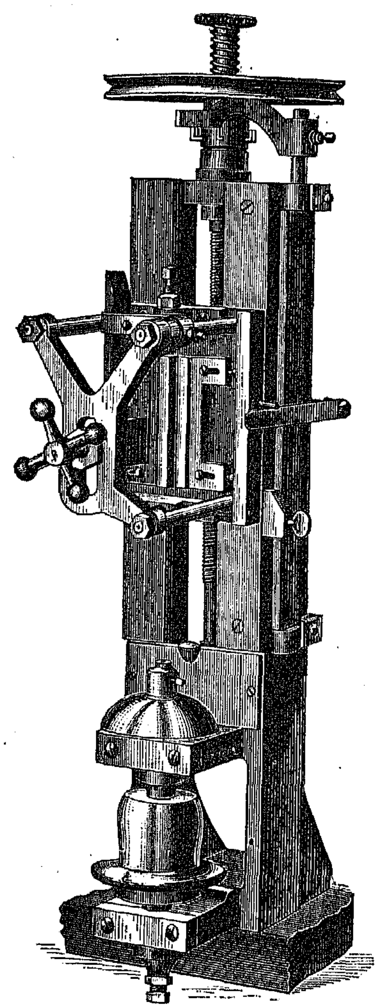

FIG. 7.

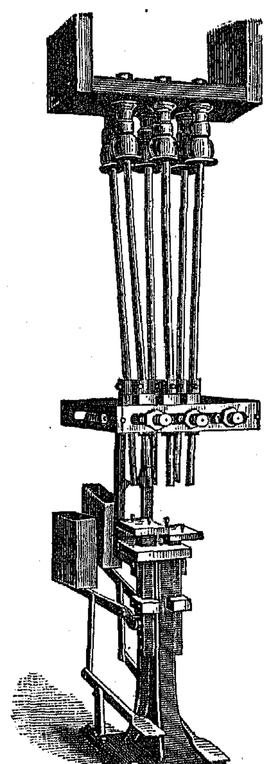

FIG. 8.

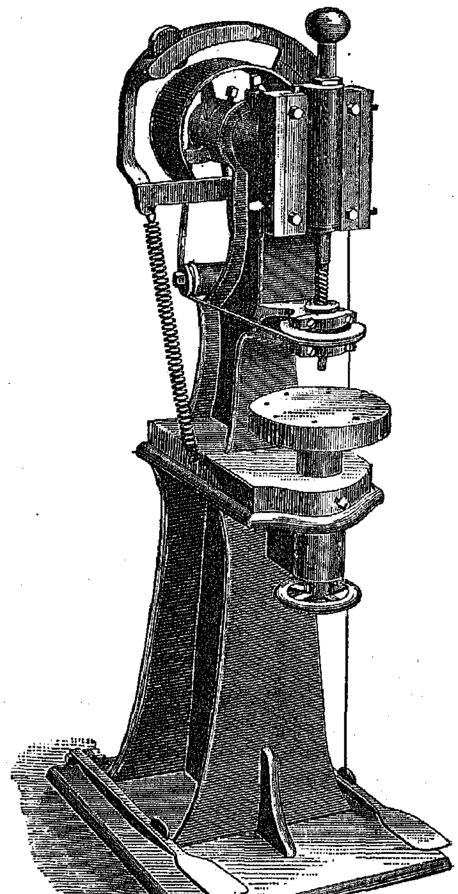

FIG. 9.

double-head drilling- and milling-machine for operating upon two sides of the work at once. This is applicable to a great number of articles, and doubles the rapidity of output for such work. Fig. 7 is an illustration of a special machine for drilling butts, in which the work, fastened upon a vertical carriage, is run down upon the drill by a feed-screw at the back of the machine, the reverse movement being by a slide upon the opening of a split nut. One boy will tend eight or ten of these machines.

In Fig. 8 is illustrated the Adt special drilling-machine, invented by Mr. John Adt, of New Haven, Connecticut, from whose designs many of our examples have been drawn. The ingenious machine in question is for drilling holes simultaneously and at variable distances apart, the spacing being adjustable and the spaces regular or irregular. It is shown arranged for drilling the screw holes of hinges, for which it is specially adaptable, the holes in hinges being out of line.

Riveting is an important work in hardware, having to be performed not only on butts and hinges of all kinds, but upon locks, castors, curtain fixtures, and many other articles.

In Fig. 9 is an illustration of an elastic blow-riveting machine, which strikes from 800 to 1,000 blows a minute, doing the work more than twice as cheaply as hand riveting, and making unskilled labor available. The hammer rotates while the blows are being given, and may be instantly stopped by a self-acting device.

Special brass butt machinery is sometimes employed doing the bending, grinding, countersinking, and wire-driving with great economy of labor. Six machines will turn out 3,600 pairs of butts a day, and enable the operatives to do five or six times the previous hand work.

These examples will be understood to be merely items of the many special devices applied in the manufacture of hardware, but some of the most general of the many kinds of work have at least been touched upon. Manufacturers using machines of their own special design are often very reasonably unwilling to have publicity given to their labor-saving features. This, however, is unnecessary, for while the examples and descriptions of labor-saving machines might be indefinitely extended, enough has been given (without trenching upon private specialties) to indicate the general character and direction of the work.

The improvement in polishing and grinding has not been inconsiderable, this having been principally due to the more extensive use of emery, whether glued upon leather-covered wheels, or made up into solid wheels, or wheel-rims of tanite, vulcanite, or celluloid.

In consequence of improvements in the mechanical part of the work the work of packing becomes relatively more important, not infrequently requiring 15 or 20 per cent. of the whole number of hands.

II.—THE MANUFACTURE OF CUTLERY AND EDGE-TOOLS.

The caption "cutlery and edge-tools" is made to include some articles which might, perhaps, be more properly called "point tools", but whose association in their nature and in their manufacture makes the heading used a convenience. In separating fine cutlery, shears and scissors, axes and picks, stone tools and drills, and augers, from the general residuum of cutlery and edge-tools, the object is chiefly to exhibit the conditions of the manufacture of these articles. The manufactures specified under "other cutlery and edge-tools" doubtless include the production of many articles which, if more definitely returned, might go to increase the volume of the preceding classes. The manufacture of fine cutlery is taken to include table and pocket cutlery, razors and swords, where these articles are specified. Picks, drills, and needles are often manufactured in connection with axes, especially in the mining regions. Well-augers are commonly manufactured in connection with drills and stone tools, and mill picks, ice tools, and oil tools are included in the same class. The class "augers" applies principally to wood-boring augers.

The value of material consumed per operative for the several classes is in the following order: Axes and picks, stone tools and drills, fine cutlery, scissors and shears, and augers, there being often double the work upon the same weight of fine cutlery as compared with axes. The ratios of product to material are in nearly the inverse order: augers, scissors, and shears, fine cutlery, axes and picks, and stone tools and drills. For axes the value of material is little more than doubled, and for augers and scissors more than trebled, in the process of manufacture.

The material for ax-polls (bar-iron) fluctuated greatly during the year, the maximum value being in the state of New York about $100 per ton, and the minimum much less than half that value. Under the same conditions, a large factory will consume more material per operative than a small shop, and will have a lower ratio of product to material; but as identical conditions rarely exist, comparisons have to be taken in the rough. The principal difference is due to the weight of the individual articles produced, it being obvious that a small shop turning out mining picks and needles will handle a greater weight and value of material per operative than the largest factory making scissors or penknives. So also in the cost of labor and materials the value of net incomes and the economy of methods of manufacture vary so much that it is necessary to eliminate many of these conditions before we can judge with assurance of the law governing any one of them. Of course, mathematically, no rigid elimination may be feasible, but a knowledge of facts and of laws may afford such logical equations as will permit reasonable solutions of such questions.

In making axes the value of accessory materials (forge coal, grit, emery wheels, glue, tools, and other materials) is often nearly as great as that of the constituent materials, ax-steel and bar-iron. In making bits and augers for boring wood bar-steel is the constituent material, and coal, emery, grit, and glue are the principal accessory materials. Of the cost of iron and steel in axes a number of examples of factory products shows the percentage of steel to be from 18 to 37½ per cent. by weight and from 45 to 87½ per cent. by cost. For a small ax, the iron poll is relatively smaller and the steel bit relatively larger. The iron and steel in a dozen axes of a light grade sometimes cost as little as 90 cents, but for the heavier sizes they cost considerably more. The average ax may be considered to weigh from 4½ to 5½ pounds. Axes are commonly sold in dozens of assorted sizes, the materials for a dozen assorted between 4½ and 5½ pounds being about 62 pounds bar-iron and 10 pounds ax-steel. About 20 pounds of forge coal, one-third of a pound of borax, 1 pound of grit (grindstones), and a few cents' worth of vermilion are also consumed, beside the emery used in polishing, which is a considerable item of expense. In working under the hammer, grinding, and polishing, the weight of raw material is reduced about one-sixth. Boxing material costs about 25 cents per dozen axes. In a large factory every item of cost (which for a small product might seem trivial) mounts up to a great sum per annum, and by its importance stimulates the more careful provision for minor details of the work.

The manufacture of swords and razors is classed with "fine cutlery", and although these manufactures may be considered of a finer grade than those of pocket and table cutlery, they are scarcely extensive enough to warrant the formation of a separate class. Before 1831, the world over, sword-blades were made of double-shear or laminated steel (so called from being piled twice, single shear, a poorer quality, being piled only once), but in that year the use of cast-steel for swords was introduced by the Ames Manufacturing Company, of Chicopee, Massachusetts, and soon became the criterion of excellence. For a 23-inch long saber blade 29½ ounces steel are required, and 35 per cent. of the material is lost in the process of manufacture. A 5-foot (diameter) grindstone is consumed in the grinding of between one and two thousand sword blades.

A large proportion of the capital employed in the manufacture of heavy cutlery and edge-tools is required by the carrying of material. This is the most important distinction in reference to the capital requirement. Taking the census returns for axes and picks, stone tools and drills, augers, scissors and shears, and fine cutlery, we have in round numbers:

	PER OPERATIVE.	
	Capital.	Materials.
Axes and picks	$1,188	$615
Stone tools and drills	918	457
Augers	718	298
Fine cutlery	641	331
Scissors and shears	361	325

The exception with reference to wood-boring augers may be ascribed to the fact that this manufacture involves special machinery and facilities quite different from those of the other classes. For cutlery and edge-tools not otherwise specified the capital is $1,057, and the materials cost $439 per operative, the plant required being obviously much more expensive than that employed in the manufacture of stone tools and drills.

That the cost of carrying stocks of material is the chief factor of the capital investment also appears from comparison with the statistics of past census years, the growth of factories in size having less influence than the consumption of materials. A large element of machinery in this work is not rated as machine plant, but as materials. The grindstones wear away rapidly, and are kept in stock as grit, the same being true of the emery wheels and belts. The principal expense of machine plant is thus confined to the forging machinery and the machinery for the generation and transmission of power. It is notable that the expense of power is relatively much greater in the employment of small engines and boilers. This is partly due to economy of coal and in attendance (a heavy item for small shops), and partly to the greater first cost of small engines per rated horse-power. In a large factory in full operation less power also runs to waste.

These industries, in point of capital investment, are not comparable with the manufacture of sewing-machines, of agricultural implements, or even of files. No such difference exists in the agencies employed between the large and the small shops, as all but the smallest jobbing and tool-sharpening shops must have trip-hammers and grindstones run by power. These industries also, being less highly organized than the manufactures of interchangeable mechanism, will be found, as a rule, in less thickly-settled localities.

Ordinary trip-hammers, such as are used in ax factories, will average a cost of about $800, ranging from $600 to $1,000, according to weight, but the special rolls and forging-presses employed in some of the large works are much more costly. Of emery wheels a stock of from six to twenty is kept for each frame, and when used in polishing axes, well mounted upon axles, cost about $15 each. The expense of duplicating machinery is greatly diminished for the large works. We may compare the actual number of machines used by 150 operatives in an ax factory with the number used by 6 operatives in another factory multiplied by 25:

For 150 operatives in one factory.	For 6 operatives in one factory.	For 150 operatives in 25 factories, 6 operatives each.
3 pairs shears.	1 pair shears.	25 pairs shears.
20 trip-hammers.	4 trip-hammers.	100 trip-hammers.
37 grindstone pits.	2 grindstones.	50 grindstones.
30 polishing frames.	2 polishing stands.	50 polishing stands.
90 machines.	9 machines.	225 machines.

This is a very instructive exhibit of the waste of doing things in a small way. Not only is there a much greater relative expense in the first cost of machines, but the machinery in the small shop, as compared in usage with that of the large shop, appears to stand idle over half the time. It is not, however, always within commercial practicability to manufacture a given product on the largest scale, and even large factories often pass from one specialty to another, until there is accumulated a large plant of special machinery, much of which is not in active or continuous use. In practice about two-thirds of the operatives are machine tenders or work with power machines.

The manufacture of fine cutlery requires less heavy machinery, less power, less consumption of material, and a much smaller ground-plant per operative employed, than that for axes. The capital requirement is therefore much smaller, although the average factory enrolls a much greater number of operatives. The average number of operatives per factory is: For fine cutlery, 65; for axes and picks, 49; for scissors and shears, 28; for augers, 19; and for stone tools and drills, 9; while for cutlery and edge-tools not specified it is 18, and the general average for all cutlery and edge-tools is 25. In previous census years the averages were: Cutlery and edge-tools, in 1850, 17; cutlery, in 1860, 26; edge-tools and axes, in 1860, 17; axes, in 1870, 36; cutlery, in 1870, 26; other edge-tools, in 1870, 23. The average number of operatives per establishment for all classes appears to have diminished since 1870, but the total number of factories has been greatly increased

For the labor upon 5 and 6 pound (assorted) axes the cost of job-work in the various departments of labor is estimated as follows, the whole labor of manufacturing being taken as a unit:

Turning polls	0.053	
Welding polls	0.064	
Drawing bits	0.171	
Hammering heads	0.210	
Forging		0.498
Edging	0.029	
Pressing	0.037	
Grinding after tempering	0.159	
Grinding		0.225
Tempering		0.054
Polishing		0.192
Packing		0.031
		1.000

Or, omitting the packing, we may say, roundly, one-half for forging, one-fourth for grinding, one-fifth for polishing, and one-twentieth for tempering.

By piece-work a grinder can at best make $3 a day, a head-hammerer $2 50, and a bit-maker about $2.

The amount of supervision required may be surmised from the fact that in the large factories there is usually one foreman to every 20 to 40 operatives. In this respect there is no very notable contrast with factories making interchangeable mechanism. In both cases, as a rule, the larger the factory the greater may be the number of men to one foreman, but since the apportionment of work as orders come in is one of the foreman's most exacting duties the source and permanence of the market demand are an important factor in determining the amount of superintendence necessary.

Each trip-hammer requires two attendants, some of the trips being employed in working stock; but of those employed in turning out axes it is estimated that one trip-hammer will turn out about 48 broad-axes (in 1828 one man forged and tempered 8 broad-axes per day), 150 common axes, or 250 hatchets in a day.

In making augers we may estimate one-tenth of the work as forging and one-twentieth as filing, and although the special machines (none of which are automatic) require some hands, by far the greatest proportion of the operatives are grinders and polishers. Since 1870 it is claimed that a general improvement of about 25 per cent. has been made in the productive efficiency of the work, due to better helve and pony hammers and the introduction of solid emery wheels and improved heading and other machinery.

In making swords about one-third of the labor is in grinding, one-fourth in polishing, one-sixth in forging, one-eighth in milling, and one-eighth in tempering, not including some common labor and work of inspection. The product per operative employed is 12 or 15 blades a day.

In making table cutlery, grinding, polishing, and handling are the portions of the work requiring most operatives. The blades and hafts were first forged by hand. The employment of the trip-hammer in forging these small blades was an American innovation, and when the practice of striking up the bolsters for the handles by means of trip-hammers was introduced, superseding hand-swaging, it raised the daily product of two men (then a smith and a striker, now a hammer-man and a helper) for this process from 150 to 3,000 blades a day. The cutting out and plating or shaping of the blades is done by power presses.

In recent years a greater amount of labor has been saved in the manufacture of light than in that of heavy cutlery. It is some evidence of this that while the value of material handled per operative in 1880, as compared with 1870, is less for axes (on account of the lower price of materials), it is notably greater for the average of other cutlery, despite the diminution in the cost of materials, indicating a greater value of materials handled per operative. The change in ratios of product to material bears out the same indication.

An attempt has been made to make an estimate of the proportions of skilled and unskilled labor upon the basis of the times, rates, and wages paid, reported by the several establishments. Theoretically, N being the total number of operatives in a factory, if we deduct the unskilled wage from the skilled wage and from the average wage, and divide N times the latter remainder by the former, we have the number of skilled workmen. The fact that time of work, stated wages, and wages paid are often incommensurate, mainly on account of the influence of variable or piece-work wages, has obliged many modifications of this rule; but it would appear from the calculation that in the two large classes of fine cutlery and cutlery and edge-tools not otherwise specified much the greater proportion of labor paid at the stated skilled wages was in the smaller factories. Thus the percentage of skilled labor for three classes arranged according to size of factory would appear as follows:

Factories, with number of operatives.	Fine cutlery.	Cutlery and edge-tools (not otherwise specified).
	Per cent.	*Per cent.*
Under 10	42	39
Between 10 and 50	35	31
Over 50	15	12

For the other classes the same rule generally prevailed when the number of establishments in the specified classes was large enough for a fair general average. The proportion of skilled labor appears greatest in the manufacture of stone tools and drills (in which there are no very large factories); next in the manufacture of augers, scissors, and shears; next in the manufacture of axes; and least in the large factories for the manufacture of fine and general cutlery. The employment of labor has been most steady in the manufacture of axes and least steady in the manufacture of fine cutlery and scissors and shears. The statistics relative to the employment of women and youths are considered to involve no contradiction of the inferences drawn from similar statistics in the manufacture of hardware, for, considering the relative growth of the lighter manufactures of cutlery, the employment of women and youths, insignificant at the most, is probably not as great as in 1870 for the same grade of work.

The power required in the manufacture of axes and heavy edge-tools is nearly twice as much per operative as is required for the lighter grades of cutlery. The horse-power per ax is found in several factories to range from 2 to 8 horse-power per hour. Thus at 4 horse-power per hour, a factory using 20 horse-power would turn out 50 axes, and one using 200 horse-power would turn out 500 axes per day of ten hours. Per operative, the horse-power is usually between 1 and 2 for axes and heavy cutlery and less than 1 for light cutlery. In ax manufacture 3 or 4 horse-power per machine (including trip-hammers) is usual. The grindstones consume a great part of this, and everything depends upon the heaviness of the work. The labor of grinding down the bit has in some cases been reduced by milling.

The processes in some of these manufactures may be briefly enumerated. For axes the stock is first cut up by power shears and worked under the steam- or trip-hammer. The poll or wrought-iron part is formed under the hammer, or in some cases by special ax-trips or in poll-rolls, which are roll presses, in which the ax-poll is shaped between two heavy rolls. The steel part or bit is then tongued into the poll and welded to it, is then drawn to a point, and the head is finished by hammering. The first operation of grinding is called pressing. The operative commonly sits upon a teetering saddle, upon a spring, and brings his weight to bear in pressing the ax against the stone. After this follow operations of grinding and edging, the grinding in some cases not being completed until after the tempering. The consumption of grindstones varies with the hardness of the metal. In grinding axes several pounds of steel are usually ground off with every pound of stone, and in making swords a greater weight of stone than of steel is ground off or consumed. Much of the stone is not ground off in the actual work, but is taken off in the truing of the stone. Formerly every workman trued his own stone, a disagreeable as well as a wasteful operation. In this duty grinders were often careless about how much they hacked off, especially if prejudiced against a stone; but now in large shops the truing is intrusted to particular men, who use a milling device which trues the stone more evenly and economically.

Tempering requires much technical judgment, and the production of finer grades of edge-tools in this country is mainly due to a better and more scientific knowledge of its requirements. It is generally stated that in order to temper a tool properly the temper must be drawn to a certain color, thus, brownish yellow (490° F.) for cold-chisels, purple (530° F.) for scissors and table cutlery, and pale blue (550° F.) for swords; but the color requisite for the best temper depends in some degree upon the metal used, and there is great room for judgment. The color for axes may be a pigeon-blue and it may be a brownish color mottled with purple, and is subject to variations not easy to describe nor uniform with all brands of steel. In the hardening and drawing of the temper of axes and other edge-tools there has been a notable mechanical improvement in the employment of revolving apparatus, by which more uniform results are obtained. After the tempering, polishing upon emery wheels and such finishing operations as bronzing, painting, and packing make the ax-head ready for the market.

In making augers the operations are shearing, drawing stock under the hammer, heading lip, twisting, crimping, grinding, burring, cone-screwing, milling, hardening, polishing, and filing. The heading or upsetting of the lip is an operation in which special machinery is employed with great advantage. Twisting is done by hand machines and crimping by both hand and power machines, and the peculiar form of the product affords scope for several forms of special grinding- and polishing-machines, but even then the work has to be completed by filing.

In the manufacture of pocket-knives and other fine cutlery the work of making and putting on handles involves many operations. Most of this is bench work, and where the cutlery is of a fine or ornamental character a large proportion of the operatives is employed upon it. It was in connection with the ornamental work upon the hilts and scabbards of swords that the practice of electroplating was first introduced into this country.

In the manufacture of sword blades, after the proper working of the stock, the shank is drawn out under a hammer and forged to shape under a drop, and the blades are drawn out by rolls in a manner similar to that employed in forming bayonets. In these rolls the back is first formed, then in two operations the face, and then the two side-grooves and the point, requiring an operation each. The blades are then bent to form, straightened, tempered, and ground, and the shanks are milled. The loss in tempering does not exceed 5 per cent. The rapidity of the second grinding is six times as great as that of the first.

III.—THE MANUFACTURE OF SAWS AND FILES.

In classifying the industries of saw- and file-making the division is made: Files, saws, and saws and files, it being understood that the manufacture of saws and files together is limited to a few establishments, in which the manufacture of saws is the more important element. The industries are kindred in many respects; both involve niceties of process in tempering and hardening; and, despite the use of files in nearly every mechanic art, the great proportion of them are used for filing saws.

Reference has been made to the displacement of hand filing by planing and milling in machine-shop work. It is not, however, to be presumed that this change caused a diminution in the manufacture of files, especially in this country, where their manufacture had been scarcely begun when planers and milling-machines were introduced, reliance having previously been placed upon importations of files from England.

Planing and milling metal, like wood planing and sawing, occupy a sphere which could never have been filled by hand filing, but machine tooling has changed the character of file-making, superseding rough files, which once constituted the greater part of all made. At the same time there remains an increasing demand for the finer classes of files, in both wood and metal finishing, and a great demand for saw-files. Thus the manufacture of files progresses with other industrial developments, but relatively falls behind many of them.

In the census tables of 1850 and 1860 file-making does not appear as a distinct industrial item, not having become of sufficient importance. Files were made by hand prior to 1850, and in connection with gun work in this country probably much earlier. The number of large factories has not increased since 1870, although many of these factories have increased greatly in size; but the number of small factories or shops (with less than 10 operatives each) has nearly doubled, and these small shops will average fewer operatives each than in 1870. This merely shows the widening of the distinction between file manufacturing and custom file-making. Between the two influences the average size of factory is only slightly increased.

In machine file-making we may reckon the value of constituent material (refined cast-steel) at 18 or 20 per cent. of the product value, the accessory material costing about half as much more.

For hand work the value of material handled per operative is usually from 60 to 75 per cent. as great as in the machine file-making works; but the figures do not fully represent the intrinsic difference in the quantity of materials handled per operative, as the larger works have better facilities for procuring their supplies at low rates. The ratio of material to product is also less in the small shops. But in the face of the market fluctuations just prior to the taking of the last census we must expect exceptions to general rules, since when the price of iron doubles within six months, only to fall to its former level in three, it is obvious that a few speculative ventures on the part of heavy concerns might greatly change the relative aspects of the returns.

Subject also to these exceptions we may note that, in saw manufacture, the largest works often show the smallest value of material per operative. This will be found mainly due to variations in the range of work. Thus, if to a saw factory employing 60 hands there be added a steel works of 40 hands, the actual cost of constituent material is not only greatly reduced in itself, but, per operative, experiences an additional reduction, so that we find ratios nearly as four to one in the value of material handled per operative. For the smallest file- and saw-shops the relative value of material, as well as of product per operative, is increased by the labor of proprietors not enumerated as operatives.

The value of saw material is from 40 to 50 per cent. of that of the product, and the cost of constituent material may be rated at 35 to 40, and of coal at 2 to 4 per cent. of the value of the product. Until after the civil war saw plates for the better quality of saws were imported from England, but since that time great advances have been made in steel manufacture in this country, and both saw steels and saws of the finest quality are now made on a large scale.

A much greater value of capital per operative is required in saw- than in file-making, the material employed per operative being of much greater value, and the plant of machinery and buildings is in every way more costly. But these differences are less strongly marked in comparing saw manufacture with machine than with hand file-making. There is also less difference now than in 1870.

In studying industrial conditions easy inferences from an inadequate knowledge of the facts are often contradicted by the statistical exhibit which may indicate unpremised conditions that really exist. It may be said in the abstract that an industry pursued in a given way attains a maximum efficiency when of a given size, but the limitation is more commonly due to the market than to the methods of manufacture. Yet in these methods, when division of labor ceases, the increase of efficiency also ceases. It then becomes a mere question of least common multiples. Thus, when files are made by hand, a few operatives may equably cover the whole work; but with the introduction of machine work the efficiency of a file-cutter is, we may say, quadrupled, and not only must the relative number of operatives working with him be also quadrupled, but new divisions of labor and administration may be introduced whose highest efficiency may remain to be satisfied with a higher multiple. So factories grow, but works greater in aggregation than in organism may be maintained by reputation of the locality and by the facilities of invested capital not easily convertible to other uses. It has been remarked that, as a rule, the largest factories have the largest capital per operative, but this rule has its general limitations, as well as its special exceptions. Where an investment already exists and must be utilized or sacrificed, capital may become cheap. Cheap capital is identical with small capital, and presupposes the existence of special conditions of intrinsic worth not rated as productive investment, such, for example, as natural water-powers and the relative advantage of location upon cheap land or the economy in the use of large over small steam powers or nearness to coal or iron mines. Such conditions often exist in small shops, and account for their small capital per operative; but in the case of a large established factory, aside from these primary influences, a temporary relapse in industrial activity may sink the rating of productive investment, so that a large portion of the worth derived from human labor may cease to be rated, being offset against the more favorable location or facilities of newer factories, whose investments are fully rated. When such capital is forced into a position parallel with that of natural advantages requiring no investment of labor, sooner or later a portion of the capital ceases to be considered as productive investment and becomes part of the ground upon which profitable investment is based. This declension is real, and though its appraisal may be at irregular intervals, especially upon check of growth or change of ownership, and therefore without consistency of estimate, a large factory may have a smaller investment per operative than a smaller works whose more recent investment has never been discounted from its original cost.

In industries in which large investments are bolstered up by great changes of method involving great relative advantage the second phase of this change has not been reached, and there is an almost regular increasing gradation of investment per operative from the smallest to the largest works; but when the relative advantage is consumed and a more stable condition is reached, this discrepancy is not maintained, and there is a relative declension of capital per operative for the larger factories. Such a declension is apparent in both saw and file manufacture, but is more marked in the former. There has been a fall in values since 1870, which appears to have had a greater influence on large than upon small investments, and a greater influence upon saw than upon file manufacture. Thus the larger file-works still, as a rule, exhibit the greater capital per operative, but for saw factories the opposite rule appears to prevail in the returns.

In both saw- and file-making the proportion of skilled operatives is usually large, and relatively greater in the small than in the large factories. Often all or nearly all of the operatives are skilled. The employment of women and boys is slight, and is principally confined to large works, in which packing and other simple duties have to be performed on a large scale. For the large factories the amount of desultory labor is exceedingly small.

In file-making the power employed ranges from one-half to 1 horse-power per operative, much of it being consumed in the forging; but in the manufacture of saws the power employed is usually as much as 1 horse-power per operative; sometimes, when the manufacture of steel is included, over 2 horse-power.

In making saws the rolled plate is first cut and trimmed, the teeth are then punched in toothing-machines and afterward are filed, and the saws are tempered in oil by aid of special apparatus. The tempering is completed by blazing off oil upon the surface of the plate, and, after hammering, the blade or plate is ground to a graded thickness, either by bedding the plate and pressing one side at a time against a grindstone, or by special grinding-machines, in which both sides of the saw are ground at one operation. It is then hammered and glazed or polished in several operations, after which the teeth are set and sharpened.

In making files the first process is the forging of the blank, at which a smith and striker will turn out over 200 blanks a day for an ordinary size. These blanks are annealed, straightened, ground, and (in some cases) filed level, after which follows the cutting. The cuts are produced by hand at the rate of about one a second, a short chisel being used, and parallelism of the cuts is secured by guiding upon the ridge thrown up by the preceding cut Hardening, straightening, scouring, and proving complete the file. The introduction of machine file-cutting has somewhat changed the character of the work. Large factories have been established in consequence, and these produce files of standard forms with more uniform teeth and more effective in operation than those made by hand, but hand-cutting remains necessary for custom and special work. In sharpening and resharpening files the sand-blast has in recent years been employed with a decided saving of labor.

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